Response Functions for Charge-Changing Weak Interactions*

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We calculate the response of charge changing hadronic interactions by solving the extended RPA problem including nucleonic ph-states and Δh-configurations. The response of a nucleon to a spin-isospin sensitive probe is of major interest for the study of charge changing excitations as they typically occur in β-decay processes and quasielastic neutrino scattering experiments. Despite the large N-Δ energy gap, the Δ-components affect considerably the nucleonic ph-sector. Hence, quenching effects due to Δh-coupling are reasonably accounted for.

In our approach nuclear density functional theory is used for the description of the nuclear matter ground state and excitations. The residual p-h interaction is then derived self-consistently by applying Landaus Fermi-Liquid theory. As a result, our response function calculations are free of additional adjustable model parameters. The response functions to an external probe entering into cross sections are related to the imaginary part of the polarization tensor, which is calculated by solving the Dyson equation, $\hat{\Pi} = \hat{\Pi}^0 + \hat{\Pi}^0\hat{V}\hat{\Pi}$, where $\hat{\Pi}^0 = \hat{\Pi}_{ph} + \hat{\Pi}_{\Delta h}$ is the in-medium polarization propagator including p-h and Δ-h states. The mixing between these states is embodied in the residual interaction $\hat{V}$ and leads to a quenching of the quasi-elastic peak. In our work $\hat{V}$ is calculated from the second order variation of the energy density functional with respect to the corresponding spin-isospin densities. With this approach our interaction exhibits a more genuine density and isospin dependence. This functional dependence is not considered in many other RPA calculations. However, our results show that it effects the strength and shape of the nuclear matter response. To properly account for nucleonic excitations in the spin-isospin channel as well as charge asymmetric ground states we extend $\hat{\Pi}^0$ to include density and isospin dependent self-energies in the neutron, proton and Δ propagators [1]. For the Δ self-energies we use a many-body approach which includes higher order quasielastic corrections in terms of two- and three-body absorptions [2]. The response functions for a finite nucleus are calculated in the local density approximation. For our calculations we use HFB proton and neutron ground state densities, which in case of quasi-elastic electron scattering provide a satisfactory description of the data as shown in Fig. 1.

Our results are in good agreement with other calculations in the considered energy-momentum region [3]. Furthermore, our approach provides a better understanding of the fundamental spin-isospin in-medium interactions. The higher order effects included in the residual interaction mostly affect the shape and strength of the quasielastic peak, where the self-energy insertions adjust the position as well as the width of the quasielastic peak. Fig. 2 shows typical quasielastic neutrino scattering results for some nuclei.

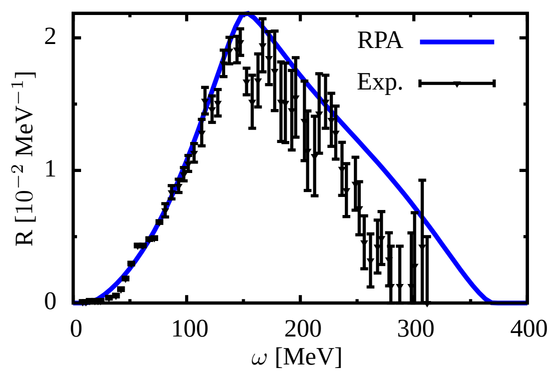

Figure 1: Quasielastic peak of the longitudinal electron scattering response for fixed $\vec{q} = 550$.

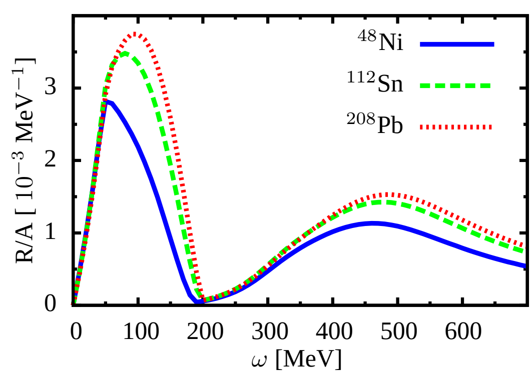

Figure 2: Longitudinal response per nucleon for neutrino scattering on different targets at $\vec{q} = 300$ MeV

References

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* Work supported by HGS-HIRe.
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